VARIABILITY IN CONE MORPHOMETRIC CHARACTERS AMONG TEST TREES OF BALD CYPRESS (*Taxodium distichum* L. Rich.) IN SEED STAND NEAR BAČKA PALANKA

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Abstract: *Bald cypress is monoecious, long-lived, deciduous conifer. It belongs to the family Taxodiaceae and genus Taxodium. In Serbia, there is only Taxodium distichum (L.) Rich. that mostly can be found in the green areas of major cities. The possibility of wider application of Bald cypress as a forest species should be based on an assessment of its genetic and adaptive potential, quantity and quality of yield, primarily at the level of the existing Bald cypress seed stand. In this paper are presented research results of the variability in cone morphometric characters among 20 test trees. The determined values of cone dimensions indicate good genetic and adaptive potential of this species that can be considered as starting point for the mass production of quality seed and planting material in Serbia.*

Key words: Bald cypress, cone, seed, variability.

VARIJABILNOST MORFOMETRIJSKIH SVOJSTAVA ŠIŠARICA TEST STABALA TAKSODIJUMA (*Taxodium distichum* L. Rich.) U SEMENSKOJ SASTOJINI KOD BAČKE PALANKE

Izvod: *Taksodijum je jednodomi, dugovečni listopadni četinar. Pripada familiji Taxodiaceae i rodu Taxodium. U Srbiji je zabeležen samo Taxodium distichum (L.) Rich. koji se uglavnom javlja pojedinačno na zelenim površina većih gradova. Mogućnost šire primene taksodijuma kao šumske vrste treba bazirati na proceni njegovog genetskog i*

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adaptivnog potencijala kao i kvantiteta i kvaliteta uroda, pre svega, na nivou postojeće semenske sastojine taksodijuma. U radu su prikazani rezultati ispitivanja varijabilnosti morfometrijskih svojstava šišarica na nivou 20 test stabala. Utvrđene vrednosti dimenzija šišarica ukazuju na dobar genetski i adaptivni potencijal ove vrste, što se može smatrati polaznom osnovom za masovnu proizvodnju kvalitetnog semenskog i sadnog materijala u Srbiji.

Ključne reči: taksodijum, šišarice, seme, varijabilnost.

1. INTRODUCTION

Bald cypress is monoecious, long-lived, deciduous conifer. It belongs to the family *Taxodiaceae* and genus *Taxodium* that includes three species (V u k i ć e v i ć , 1987). In Serbia, there is only *Taxodium distichum* (L.) Rich. Bald cypress capability for establishment of forest cultures on lowland and floodplains of our country was recorded in the 1950s (P e t r o v i ć , 1951; Š p i r a n e c , 1959, 1966). At the beginning of the 1980s, S t i l i n o v i ć a n d T u c o v i ć (1970) concluded that in our environmental conditions Bald cypress can be considered as a species of rapid growth, one of the few conifer species that may be suitable for introduction of conifers on lowland and floodplain sites where it can achieve high productivity.

Nevertheless, on the territory of the Republic of Serbia this species has practically never got out from the range of horticultural activities. Researches on the variability and adaptive potential of Bald cypress in our conditions which have been published until now refer to trees that grow individually and in smaller or larger groups mainly in the city green areas (D r a ž i ć , B a t o s , 2002; N i n i ć - T o d o r o v i ć , O c o k o l j i ć , 2001, 2002; T u c o v i ć , O c o k o l j i ć , 2005). The possibility of wider application of Bald cypress as a forest species should be based on an assessment of its genetic and adaptive potential as well as quantity and quality of yield, primarily at the level of the existing Bald cypress seed stand.

2. MATERIAL AND METHOD

Researches were conducted in Bald cypress seed stand in Bačka Palanka, registration number S 01.10.01.01, which is managed by FE Novi Sad, FA Bačka Palanka. Seed stand is within MU "Palanačke Ade- Čipski poloj", Department 11, Section a, with area of 0.22 ha and with 111 trees. Its origin is artificial, aged about 70 years, with the measured taxation values of mean diameter ds = 51.7 cm and mean height, hs = 26.5 m. It is located on flat ground with an average altitude of 80 m, with a uniform slope and without clear exposure. Flooding is not present, but it is heavily influenced by underground wetting. The site on which the seed stand is located belongs to coeno-ecological group of White willow and Populus (*Salicion albae*) forests on undeveloped semi-gley soils.

On the basis of phenotypic characteristics and abundance of yield in 2010, 20 test trees were selected and per 200 cones were collected from each of them. Cones were put into separate bags. Then by random sampling method 50 cones per tree were taken for processing at the laboratory of Institute of Forestry. Cone

opening was done in the dryer at the temperature of 40 °C, and seed cleaning was done manually. The basic morphometric parameters of each cone (length and width) were measured by caliper with an accuracy of 1 mm. Also, after cone opening the number of grains was determined for each cone. The obtained data were processed in a computer program Statgraph 5.0.

3. RESULTS AND DISCUSSION

Variability in cone morphometric characters of 20 test trees of Bald cypress is presented in Table 1.

Table 1. *Variability in cone morphometric characters of 20 test trees of Bald cypress*

Trees	Parameter	Average (mm)	Min	Max	Standard deviation	Coefficient of variation
1	Cone length (mm)	31.56	22.5	38.7	4.25	18.08
	Cone width (mm)	28.67	20.9	36.5	4.14	17.14
	Number of seeds (pcs.)	28,50	22,0	32,0	2,30	5,28
2	Cone length (mm)	30.70	22.6	37.2	4.07	16.56
	Cone width (mm)	28.44	22.1	36.0	3.98	15.85
	Number of seeds (pcs.)	27,22	20,0	33,0	3,38	11,40
3	Cone length (mm)	29.67	22.4	38.4	4.21	17.76
	Cone width (mm)	27.77	21.3	34.5	3.40	15.97
	Number of seeds (pcs.)	27,50	21,0	34,0	3,01	9,03
4	Cone length (mm)	30.55	22.3	38.4	3.58	12.78
	Cone width (mm)	27.97	21.0	36.2	3.47	12.06
	Number of seeds (pcs.)	27,84	21,0	32,0	2,72	7,40
5	Cone length (mm)	30.67	22.6	37.6	4.01	16.07
	Cone width (mm)	27.96	19.1	34.6	3.89	15.10
	Number of seeds (pcs.)	27,06	20,0	33,0	3,35	11,24
6	Cone length (mm)	29.54	21.4	38.4	4.31	18.56
	Cone width (mm)	26.48	19.4	35.6	4.05	16.39
	Number of seeds (pcs.)	26,08	20,0	32,0	3,30	10,89
7	Cone length (mm)	30.25	21.5	38.4	4.47	20.00
	Cone width (mm)	26.97	18.6	35.1	4.26	18.15
	Number of seeds (pcs.)	26,66	20,0	33,0	3,59	12,88
8	Cone length (mm)	29.05	21.3	37.5	4.47	19.95
	Cone width (mm)	25.85	19.4	34.6	4.30	18.45
	Number of seeds (pcs.)	25,40	20,0	33,0	3,58	14,82
9	Cone length (mm)	29.84	20.6	37.1	4.15	17.20
	Cone width (mm)	26.01	8.0	33.8	4.89	23.95
	Number of seeds (pcs.)	25,90	21,0	32,0	3,60	12,95
10	Cone length (mm)	29.08	21.3	38.4	4.26	18.11
	Cone width (mm)	25.73	19.5	34.1	4.23	17.93
	Number of seeds (pcs.)	25,44	20,0	32,0	3,60	12,99
11	Cone length (mm)	28.41	22.3	36.5	3.37	11.35
	Cone width (mm)	25.27	20.1	33.2	3.38	11.45
	Number of seeds	25,76	20,0	33,0	3,28	10,76

Trees	Parameter	Average (mm)	Min	Max	Standard deviation	Coefficient of variation
	(pcs.)					
12	Cone length (mm)	28.84	22.3	36.5	3.29	10.84
	Cone width (mm)	25.96	19.9	33.6	3.40	11.59
	Number of seeds (pcs.)	26,30	21,0	33,0	2,99	8,95
13	Cone length (mm)	28.73	21.8	34.3	3.00	9.00
	Cone width (mm)	25.82	19.9	31.8	2.98	8.89
	Number of seeds (pcs.)	26,08	20,0	33,0	3,15	9,95
14	Cone length (mm)	28.99	21.3	36.1	3.44	11.81
	Cone width (mm)	25.96	19.9	33.2	3.26	10.65
	Number of seeds (pcs.)	25,86	20,0	33,0	3,34	11,14
15	Cone length (mm)	28.64	23.6	35.2	3.27	10.71
	Cone width (mm)	25.58	20.9	31.5	3.19	10.20
	Number of seeds (pcs.)	25,20	20,0	33,0	3,73	13,88
16	Cone length (mm)	28.90	23.6	34.5	2.79	7.76
	Cone width (mm)	25.53	19.6	30.8	2.96	8.75
	Number of seeds (pcs.)	25,56	20,0	31,0	3,03	9,19
17	Cone length (mm)	28.99	22.8	36.2	3.49	12.17
	Cone width (mm)	25.78	19.5	31.2	2.98	8.86
	Number of seeds (pcs.)	26,46	21,0	32,0	2,68	7,19
18	Cone length (mm)	29.13	23.6	35.2	2.96	8.74
	Cone width (mm)	26.35	21.2	32.3	2.81	7.90
	Number of seeds (pcs.)	26,74	22,0	32,0	2,48	6,16
19	Cone length (mm)	29.34	24.3	35.6	2.92	8.51
	Cone width (mm)	26.59	21.3	32.6	3.06	9.34
	Number of seeds (pcs.)	27,08	21,0	33,0	3,04	9,22
20	Cone length (mm)	29.07	23.0	35.9	2.80	7.85
	Cone width (mm)	26.05	21.0	32.1	2.50	6.25
	Number of seeds (pcs.)	26,40	21,0	32,0	2,47	6,12

Based on the statistical indicators, it can be concluded that the highest mean value of cone length shows a test tree marked with number 1 (31.56 mm), while the smallest mean value of cone length has the test tree marked with number 11 (28.41 mm). The highest mean value of cone width has the test tree marked with number 1 (28.67 mm) and the smallest mean value of cone width has the test tree marked with number 11 (25.27 mm). The highest mean value of number of grains has the test tree marked with number 1 (28.5 pieces), and the smallest mean value of number of grains has the test tree marked with number 15 (25.2 pieces.). Test tree marked with number 1 stands out like the best for all three characters, while the test tree number 11 has the smallest mean value of cone length and width, but not the number of grains. The values of the analyzed characters coincide with the values that in their researches obtained other authors. In Motovun forest, Croatia, Bald cypress cone diameter ranges from 20 to 25 mm and one cone contains from 18 to 30 grains (Š p i r a n e c , M . 1959.). Under Belgrade's environmental conditions cone diameter ranges from 20 to 30 mm (D r a ž i ć , D . , B a t o s , B . 2002.). Under the environmental conditions of Bulgaria cone diameter ranges up

to 30 mm, cone length from 20 to 40 mm, and cones contain approximately 20 to 25 grains (M i l e v , M . , et al. 1999.). In Bald cypress population at Veliko Ratno ostrvo, cone diameter ranges from 22 to 39 mm, and cones contain from 10 to 32 grains, on average about 20 grains (Š i j a č i ć - N i k o l i ć , M . , et al. 2011.).

The coefficient of variation can be used as an indicator of statistical set homogeneity. By analyzing the values of this coefficient, we can conclude that for the cone length character the most homogeneous is the test tree marked with number 16 (7.76), and the most heterogeneous is the test tree marked with number 7 (20). For the cone width character, the most homogeneous is the test tree marked with number 20 (6.25), and the most heterogeneous is the tree test marked with number 9 (23.95). For the character number of grains, the most homogeneous is the test tree marked with number 1 (5.28), and the most heterogeneous is the test tree marked with number 8 (14.82).

ANALYSIS OF VARIANCE

1. Cone width

Table 2. *Analysis of variance for cone width*

	Sum of Squares	Df	Mean Square	F- Ratio	P- Value
Between groups	1045.11	19	55.0058	4.15	0.0000
Within groups	12977.8	980	13.2427		
Total	14022.9	999			

Results of analysis of variance (Table 2) show statistically significant differences at level p <0.05 between cone width of 20 Bald cypress test trees.

Table 3. *LSD test*

Trees	Mean	Homogeneous groups
11	25.2700	X
16	25.5300	X
15	25.5806	XX
10	25.7298	XX
17	25.7780	XX
13	25.8180	XX
8	25.8500	XX
12	25.9580	XX
14	25.9620	XX
9	26.0112	XX
20	26.0460	XX
18	26.3500	XXX
6	26.4800	XXX
19	26.5880	XXXX
7	26.9740	XXX
3	27.7660	XXX
5	27.9600	XX
4	27.9680	XX
2	28.4380	X
1	28.6676	X

Analysis of variance shows that the differences between the mean values of cone width of 20 Bald cypress test trees are statistically significant at the

confidence level p <0.05. Test trees are grouped into 5 homogenous groups and with that is confirmed variability of cone width of 20 Bald cypress test trees. In the homogeneous group with the greatest cone width are test trees 1, 2, 4, 5 and 3, and in the group with the smallest cone width are test trees 11, 16, 15 and 10 (Table 3).

2. Cone length

Table 4. *Analysis of variance for cone length*

	Sum of Squares	Df	Mean Square	F- Ratio	P- Value
Between groups	671.144	19	35.3233	2.58	0.0002
Within groups	13416.2	980	13.69		
Total	14087.4	999			

Results of analysis of variance (Table 4) show statistically significant differences at level p <0.05 between cone length of 20 Bald cypress test trees.

Table 5. *LSD test*

Trees	Mean	Homogeneous groups
11	28.410	X
15	28.636	X
13	28.730	X
12	28.836	XX
16	28.898	XX
17	28.988	XX
14	28.994	XX
8	29.054	XX
20	29.074	XX
10	29.080	XX
18	29.130	XXX
19	29.340	XXXX
6	29.544	XXXX
3	29.666	XXXX
9	29.844	XXXX
7	30.246	XXXX
4	30.554	XXX
5	30.670	XX
2	30.698	XX
1	31.558	X

Analysis of variance shows that the differences between the mean values of cone length of 20 Bald cypress test trees are statistically significant at the confidence level p <0.05. Test trees are grouped into 5 homogenous groups and with that is confirmed variability of cone length of 20 Bald cypress test trees. In the homogeneous group with the greatest cone length are test trees 1, 2, 5, 4 and 7, and in the group with the smallest cone length are test trees 11, 15 and 13 (Table 5).

3. Number of grains

Table 6. *Analysis of variance for number of grains*

	Sum of Squares	Df	Mean Square	F- Ratio	P- Value
Between groups	731,496	19	38,4998	3.82	0.0000
Within groups	9870,2	980	10,0716		
Total	10601,7	999			

Results of analysis of variance (Table 6) show statistically significant differences at level p <0.05 between number of grains of 20 Bald cypress test trees.

Table 7. *LSD test*

Trees	Mean	Homogeneous groups
15	25,2	X
8	25,4	XX
10	25,44	XXX
16	25,56	XXXX
11	25,76	XXXX
14	25,86	XXXXX
9	25,9	XXXXX
6	26,08	XXXXXX
13	26,08	XXXXXX
12	26,3	XXXXXXX
20	26,4	XXXXXXX
17	26,46	XXXXXX
7	26,66	XXXXXX
18	26,74	XXXXX
5	27,06	XXXX
19	27,08	XXXX
2	27,22	XXX
3	27,5	XXX
4	27,84	XX
1	28,5	X

Analysis of variance shows that the differences between the mean values of number of grains of 20 Bald cypress test trees are statistically significant at the confidence level p <0.05. Test trees are grouped into 9 homogenous groups and with that is confirmed variability of number of grains of 20 Bald cypress test trees. In the homogeneous group with the greatest number of grains are test trees 1, 4 and 3, and in the group with the smallest number of grains are test trees 15, 8 and 10 (Table 7).

Table 8. *Regression analysis*

Trees	Parameter	r	r²	p	N
1	Cone length x Number of seeds	0,548611	0,300974	0,0000	50
	Cone width x Number of seeds	0,528498	0,27931	0,0001	50
2	Cone length x Number of seeds	0,890308	0,792648	0,0000	50
	Cone width x Number of seeds	0,889399	0,791031	0,0000	50
3	Cone length x Number of seeds	0,825719	0,681812	0,0000	50
	Cone width x Number of seeds	0,81389	0,662417	0,0000	50
4	Cone length x Number of seeds	0,888308	0,789091	0,0000	50
	Cone width x Number of seeds	0,903113	0,815613	0,0000	50
5	Cone length x Number of seeds	0,940068	0,883728	0,0000	50
	Cone width x Number of seeds	0,923862	0,853521	0,0000	50
6	Cone length x Number of seeds	0,908907	0,826112	0,0000	50
	Cone width x Number of seeds	0,928016	0,861214	0,0000	50
7	Cone length x Number of seeds	0,913761	0,834959	0,0000	50
	Cone width x Number of seeds	0,913203	0,83394	0,0000	50
8	Cone length x Number of seeds	0,914862	0,836972	0,0000	50
	Cone width x Number of seeds	0,933206	0,870873	0,0000	50
9	Cone length x Number of seeds	0,912043	0,831822	0,0000	50
	Cone width x Number of seeds	0,954006	0,910127	0,0000	50
10	Cone length x Number of seeds	0,886714	0,786262	0,0000	50
	Cone width x Number of seeds	0,890744	0,793425	0,0000	50
11	Cone length x Number of seeds	0,844746	0,713596	0,0000	50

Trees	Parameter	r	r²	p	N
	Cone width x Number of seeds	0,830205	0,68924	0,0000	50
12	Cone length x Number of seeds	0,840029	0,705649	0,0000	50
	Cone width x Number of seeds	0,85299	0,727592	0,0000	50
13	Cone length x Number of seeds	0,752248	0,565877	0,0000	50
	Cone width x Number of seeds	0,793055	0,628936	0,0000	50
14	Cone length x Number of seeds	0,858214	0,736531	0,0000	50
	Cone width x Number of seeds	0,8997	0,80946	0,0000	50
15	Cone length x Number of seeds	0,885102	0,783406	0,0000	50
	Cone width x Number of seeds	0,910709	0,829391	0,0000	50
16	Cone length x Number of seeds	0,892438	0,796446	0,0000	50
	Cone width x Number of seeds	0,913385	0,834272	0,0000	50
17	Cone length x Number of seeds	0,840042	0,705671	0,0000	50
	Cone width x Number of seeds	0,825407	0,681297	0,0000	50
18	Cone length x Number of seeds	0,793743	0,630028	0,0000	50
	Cone width x Number of seeds	0,833713	0,695077	0,0000	50
19	Cone length x Number of seeds	0,864266	0,746956	0,0000	50
	Cone width x Number of seeds	0,886702	0,78624	0,0000	50
20	Cone length x Number of seeds	0,653156	0,426613	0,0000	50
	Cone width x Number of seeds	0,711399	0,506089	0,0000	50

Table 8 shows the coefficients of the linear correlation, the correlation coefficient (r), and the coefficient of determination (r^2). By regression analysis was tried to link cone length and number of grains, as well as cone width and number of grains whereby is being determined only correlation. Coefficients of the linear correlation are statistically significant for the confidence level 5%.

The correlation coefficient shows linear correlation of observed characters. A positive value of the correlation coefficient shows the positive correlation of observed characters. Increasing the value of one character leads to increasing the value of another. The coefficient of determination, as relative indicator, is used to determine the relationship of the observed characters. The relationship between the cone length and number of grains is the strongest in the test tree marked with number 5 (r^2=0,883728), and the weakest in the test tree marked with number 1 (r^2=0,300974). Relationship between the cone width and number of grains is the strongest in the test tree marked with number 9 (r^2=0,910127), and the weakest in the test tree marked with number 1 (r^2=0,27931).

4. CONCLUSIONS

The variability of the quantity and quality of yield of more important tree species is for a long time the subject of research of forest science and profession. However, the degree of exploration of the genetic variability of quantity and quality of forest trees' seed yield and the possibility of its adequate use in our country is still below the actual needs and it is not in accordance with the economic importance. Thanks to the research results of Tucović, A. (1975), Mrva, F. (1976, 1984), Popnikola, N. (1978), Tucović, A., Stilinović, S. (1982), Tucović, A., Isajev, V. (1985), Isajev, V. (1987), Tošić, M. (1991), Mataruga, M. (2003), Lučić, A. (2007), Lučić, A. (2012) etc., the knowledge has been gradually completed and relationship between genetic constitution of populations and environmental conditions has been explained closer, as well as the morphological and physiological characters of seed.

To the learning about the variability in size of cones depending on the population, genotype and collection year, contributed following papers: in Scots pine T o š i ć , M . (1991); L u č i ć , A . (2012), in Austrian pine L u č i ć , A . (2007), in Serbian spruce I s a j e v , V . (1987); T u c o v i ć , A . et al. (1982); Š i j a č i ć - N i k o l i ć , M . (2000, 2003) and in Spruce Š i j a č i ć - N i k o l i ć , M . et al. (2010).

The results obtained from the analysis of variability of morphometric characteristics of cones of 20 Bald cypress test trees originated from seed stand near Bačka Palanka contribute to better understanding of relationships of analyzed characters, as well as the influence of analyzed characters on differentiation of test trees. Based on these results differences were noticed in the values of the observed characters for the each test tree individually. The test tree marked with number 1 stands out with the highest value for all three observed characters, the test tree number 11 has the smallest value for characters cone length and cone width, while the smallest value for the number of grains has test tree number 15. By regression analysis was tried to link cone length and number of grains, as well as cone width and number of grains whereby was being determined only correlation. The relationship between the cone length and number of grains is the strongest in the test tree marked with number 5 and between cone width and number of grains in the test tree number 9. The test tree number 1 has the weakest relationship in both, the cone length and number of grains as well as the cone width and number of grains.

Conducted researches have to be continued in the direction of continuous monitoring of yield quality and quantity in Bald cypress seed stand near Bačka Palanka as the basis for the mass production of genetic quality seed and planting material of this species in Serbia.

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